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THE STUDY OF PRACTISE FORECASTING.

By J. L. BARTLETT. Dated Madison, Wis., November 19, 1906.

Anyone who attempts to forecast future atmospheric conditions from weather charts is soon confronted with the problem of classifying the great number of weather types encountered and of formulating general rules for each type or for each set of approximately similar types. After some study of the subject a retentive memory undoubtedly becomes of great value in making rapid forecasts. But for the beginner to attempt to memorize and to classify mentally the weather conditions following the various types from simply examining successive maps is often a discouraging task, especially in view of the fact that no rule of forecasting yet formulated is wholly exempt from failure. Weather forecasting under existing conditions is the problem of determining the average results produced by causes which are more or less fixt. The causes may be considered to be the existing weather conditions at the time the forecast is made; the results are the conditions prevailing during the period forecasted for.

With the foregoing in mind the scheme of tabulating weather charts and portions of their data as shown in the accompanying table has been worked out. This table shows in condensed form the weather conditions prevailing over the Northwest during November, 1905. The general idea of the scheme may be seen at once from the headings of the various columns. In selecting these headings the two great general principles of prediction were kept in view, namely—the eastward movement in this latitude of existing weather conditions, and the influence of high and low pressure centers upon the weather in their vicinities. The following method of tabulation was then carried out.

GENERAL METHOD OF TABULATION.

One line, or more if necessary, is used for the data for each weather chart. On successive lines are placed the data for succeeding charts for the whole month. Under "high" and "low", respectively, are noted the positions and values of central isobars of the high and low pressure areas nearest the section forecasted for. Distant areas, especially to the eastward, are omitted, unless of great extent, but to the westward all the more important areas are considered. In locating these areas, geographical subdivisions are used instead of quadrants, the former being more exactly defined and more easily tabulated. In the next column is noted the general location of the nearest rain, especially to the westward, during the past twelve hours. Succeeding columns contain data for selected stations, usually to the westward of the region for which forecasts are to be made, the current temperature being first; the 24-hour temperature change, when 6°, or over, second; and the precipitation, if any, third. The p. m. precipitation is in black-faced type. The selection of these stations is a matter of no little importance. As a rule only those should be considered whose temperature, temperature change, and precipitation areas are found to move over the area forecasted for with some regularity. It may be necessary to experiment with a large number of stations in the northern, western, and southern quadrants before those most suitable for study are determined.

In the columns on the right-hand side of the sheet are placed similar data for all stations within the area forecasted for, and covering the period for which forecasts are made. In the case of the accompanying table the a. m. and p. m. data for the day following are used. The resulting weather is thus kept on the same line with the preceding or causal weather, so that by looking along one line the causes producing certain results may be seen at a glance.

DATA TO BE TABULATED.

The selection of data to be tabulated depends upon the class of forecasts issued, and so may vary much for different forecasters. Under "Resulting Weather", at different seasons of the year, should be columns for data relative to high and low temperatures, cold waves, frosts, and, on the coasts, the occurrence of high winds. For careful local forecasting the division of the day, for tabulating precipitation data, into 6-hour instead of 12-hour periods may show interesting results. Under "Causal Weather" additional columns may also be introduced. If 12-hour pressure changes are computed, the position and value each day of the greatest + and — changes may be noted. The tendency of "highs" and "lows" to deviate from normal eastward movement, as indicated by Bowie's graphical method, is undoubtedly of value to tabulate. Besides temperature and precipitation data, that for wind direction and cloudiness would be of interest both under causal and resulting weather, altho the two last elements are not verified in forecasting and are quite closely associated with the centers of high and low pressure. In general, however, excess of data should be avoided and any not found to be of value omitted, thereby avoiding much confusion.

The completed sheet of data shows the weather conditions and changes over a considerable region for the whole month. The preparation of such a sheet has been found to occupy from one and one-half to three hours, depending on the amount of data tabulated. While the study of a single sheet may indicate valuable knowledge, it is thought that as a rule data for not less than five years, for any calendar month, should be considered in attempting to formulate general rules for forecasting.

THE STUDY OF THE DATA.

This is the most interesting and also the most difficult part of the work. The general aim is to learn what percentage of times a certain type of chart produces the same results. Consider, for example, the influence of Alberta "lows" on the p. m. conditions in Wisconsin thirty-six hours later. In the accompanying table such "lows" are shown on six dates, the 1st, 3d, 9th, 18th, 22d, and 25th. In five instances, or 83 per cent of the time, no rain had fallen preceding the p. m. observation thirty-six hours later; in four cases the temperature change was sufficient to have warranted a forecast of "warmer". These facts may then be incorporated into a general rule. The next step is to study such exceptions to this rule, as the occurrence of precipitation on the 2d at Madison and Green Bay, and the absence of a + temperature change on the 18th and 25th. Could these exceptions have been foreseen from any peculiarity of the causal chart, such as the existence of another disturbing pressure center, local rain areas to the westward, abnormal temperature conditions over the area forecasted for, retardation or acceleration of centers indicated by 12-hour pressure changes, or by Bowie's method? Each exception should be traced to its possible causes and a suitable exception to the rule be made. For example, the nonoccurrence of a + temperature change thirty-six hours after the chart of the 18th was due to a slight "high" in Manitoba on that date, which had caused temperatures to fall in the Dakotas; while on the 25th a "low" over Manitoba prevented the Alberta "low" from being attended by warmer weather the next day in Wisconsin. Both of these exceptions could doubtless have been foreseen in actual forecasting. If the rule, when tested, shows a low percentage of verification, it is often better to state it negatively and develop the exceptions from the latter point of view. We may then proceed to consider another type of chart and formulate another rule with its accompanying exceptions. This is continued until all the distinct types of weather charts are covered. This general method of formulating average rules, particularly with regard to precipitation, is well illustrated in Russell's Meteorology.

There is another method of approaching this study, considering the general eastward weather movement as a more important factor in weather prediction than the influence of high and low pressure centers. This seems to be true at some seasons of the year, especially during the warmer months, when areas of precipitation, cloudy weather, and high or low temperature may drift across the country more steadily than do the pressure centers which they accompany. During some months the precipitation and temperature change at any point are quite accurately indicated by the precipitation and temperature change of the previous twenty-four hours at some station to the westward. Working from this point of view, the + temperature changes of 6°, or over, at one of the causal stations are considered and the percentage of cases followed by + changes at any of the "resulting weather" stations is computed. (It seems hardly worth while to consider changes of less than 6° as they neither break a forecast of stationary temperature nor are appreciable to the public.) Falls in temperature and occurrences of precipitation may be similarly considered and average rules determined. At first but one item, as the + change, for one causal station at a time, should be considered, tho after a while it will be found that several stations may be grouped together and considered under their geographic subdivision. Thus, the causal weather at Huron and Pierre may be generalized as South Dakota weather. The exceptions to the average rules found by this method should also be studied and will usually be found to be due to the abnormal movements of pressure centers, unusual temperature conditions, or to local topographical weather controls, such as mountains, valleys, lakes, or oceans.

Doubtless it will be best to study the data both by considering the "highs" and "lows" as the fundamental weather causes, and also by attaching the greater importance to the general eastward weather movement. A large number of general rules, each with its exceptions, will be obtained, but when these are compared it will be found that many can be combined and simplified, so that finally those that are of value may not exceed a dozen in number for each month.

TABLE 1.—*Condensed form showing weather conditions prevailing over the Northwest during November, 1905.*

	Causal weather.												Resulting weather in Wisconsin							
	High.		Low.			Temperatures, 24-hour changes, and precipitation.							Temperatures, 24-hour changes, and precipitation.							
Date.	Location.	Strength.	Location.	Strength.	Nearest rain during past 12 hours.	Moorhead.	Bismarck.	Huron.	Pierre.	Omaha.	N. Platte.	Date.	La Crosse. a. m.	La Crosse. p. m.	Madison. a. m.	Madison. p. m.	Green Bay. a. m.	Green Bay. p. m.	Milwaukee. a. m.	Milwaukee. p. m.
		Inches.		*Inches.*																
1	Kansas	30.4	Alberta	29.6	Upper Michigan	10 − 8	14 −18	16 −20	20 −14	28	22	2	30 +10	42 +16	24 + 2	38 +10 .02	22 + 4	36 +12 .12	28 + 6	38 + 8 T.
2	West Virginia Nevada	30.2 30.2	West Minnesota	29.5		28 +18	34 +20	36 +20	46 +26	38 +10	30 + 8	3	36 + 6	36 − 6	36 +12	38	32 +10	30 − 6	36 + 8 .01	40 + 2
3	Kansas	30.1	Lake Superior Alberta	29.55 29.5	E. Wisconsin, Minnesota, Michigan.	30 ... .04	24 −10	28 − 8	28 −18	34	24 − 6	4	28 − 8	50 +14	28 − 8	44 + 6	24 − 8	38 + 8	32	42
4	Kentucky	30.2	Manitoba New Mexico	29.7 29.6	Kansas, Oklahoma	32	30 + 6	34 + 6	34 + 6	40 + 6	38 +14	5	44 +16 .04	40 −10 1.22	42 +14 T.	40 ... .58	40 +16	40 ... .26	42 +10	42 ... .24
5	Oregon	30.4	Missouri	29.5	W. Wisconsin, Minnesota, Iowa.	28	26	36	36	44 ... 1.56	40	6	34 −10 .02	34 − 6	36 − 6 .04	34 − 6	36 ... .38	36	40 ... .20	36 − 6
6	Kansas	30.3	Lake Ontario Saskatchewan	29.55 29.85	Wisconsin, Michigan	24	30	26 −10	26 −10	32 −12 .08	26 −14	7	32 ... .14	34 ... T.	32 ... .34	34 ... T.	32 ... T.	32	32 − 8 .28	34 ... T.
7	Idaho	30.3	Illinois	29.7	Wisconsin, Minnesota	26 ... .04	32	34 + 8	36 +10 T.	42 +10	34 + 8	8	32	34 ... T.	30	32	24 − 8	30 ... T.	32	34 ... T.
8	Idaho Arkansas	30.2 30.1	North Dakota	29.9	South Dakota	30	36 ... .06	38 ... .02	46 +10 .01	36 − 6	34	9	26 − 6	34	28	32	24 ... T.	32	26 − 6 T.	32
9	Wyoming	30.4	Alberta	29.9	Michigan	22 − 8	36	32 − 6 T.	30 −16	32	32	10	28	44 +10	30	40 + 8	34 +10	42 +10	30	42 +10
10	Kansas	30.5	Saskatchewan	29.9	Upper Michigan	28 + 6	28 − 8	24 − 8	26	38 + 6	24 − 8	11	36 + 8	56 +12	34	52 +12	36	50 + 8	30	52 +10
11	Missouri Wyoming	30.4 30.5	Lake Superior	29.85		30	34 + 6	28	32 + 6	38	26	12	42 + 6	52	40 + 6	50	38	50	42 +12	52
12	Idaho	30.5	East Ontario	29.7		34	36	34 + 6	36	36	28	13	38	30 −22	38	26 −24 T.	38	22 −28	42	32 −20 T.
13	Manitoba Idaho	30.3 30.5	Wisconsin	29.75	Upper Michigan	34	40	46 +12	46 +10	42 + 6	32	14	18 −20	36 + 6	18 −20	30	14 −24	32 +10	18 −24 T.	32
14	Iowa Oregon	30.2 30.3	Saskatchewan	29.5		26 − 8	34 − 6	24 −22	28 −18	38	28	15	44 +26	42 + 6 .02	40 +22	40 +10 .03	38 +24	34 ... T.	36 +18	40 + 8 .01
15	Idaho	30.2	Lake Superior	29.1	Upper Michigan, Manitoba.	36 +10	42 + 8	40 +16	44 +16	42	36 + 8	16	36 − 8	48 + 6	38 ... .01	42	32 − 6	38	36 ... .07	42
16	New Mexico	30.1	Saskatchewan	29.55	Upper Michigan, Southeast Wisconsin.	28 − 8	34 − 8	30 −10	38 − 6	44	32	17	42 + 6	44	40	44	36	38	40	42
17	Montana	30.0	Kansas N. Wisconsin	29.8 29.7	Upper Michigan	28	36	32	36	44	48 +16	18	30 −12	42	34 − 6	40	26 −10	36	36	38
18	Manitoba	30.1	Oklahoma Alberta	29.8 29.5		20 − 8	32	28	34	36 − 8	32 − 16	19	28	40	28 − 6	36	30	36	38	38
19	Upper Lakes Nebraska	30.2 30.2	British Columbia	29.6	Dakotas	34 +14 .02	28 ... .04	28 ... T.	30	36	26 − 6	20	28	38	34 + 6	36	32	36	40	36
20	East Ontario	30.5	Saskatchewan	29.65	Washington, Oregon	30	34 + 6	36 + 8	34	34	32 + 6	21	30	40	26 − 8	36	34	34	34 − 6	36
21	East Ontario	30.7	Utah E. Saskatchewan	29.7 30.05	Wyoming	36 + 6	32	34	40 + 6	34	32	22	32	48 + 8	26	44 + 8	30	40 + 6	30	46 +10
22	North Carolina	30.6	Alberta	29.75	Utah	26 −10	20 −12	26 − 8	28 −12	38	32	23	42 +10 T.	52 ... .18	38 +12	54 +10 T.	34	50 +10	42 +12	50
23	North Carolina	30.4	W. South Dakota	29.65	Dakotas, Minnesota	46 +20 .04	46 +26	50 +24 T.	52 +24 T.	48 +10 .12	46 +14 .24	24	42 ... .08	34 −18 .01	50 +12 .34	34 −20 .02	54 +20 .24	36 −14 T.	56 +14 .02	40 −10 T.
24	Utah	30.2	Saskatchewan W. Lake Superior	29.6 29.0	Wisconsin, Nebraska, Minnesota, Iowa, Dakotas.	26 −20 .76	20 −26 .16	26 −24 .44	30 −22 .12	38 −10 .58	32 −14 .10	25	32 −10 T.	44 +10	28 −22	34 ... .02	30 −24	38 ... .10	30 −26 T.	38 ... .02
25	Nevada	30.2	Alberta Manitoba	29.4 29.5	Wisconsin, Michigan	32 + 6 .04	30 +10	32 + 6	36 + 6	38	32	26	30	30 −14	34 + 6	32	34	30 − 8	34	34

TABLE 1.—*Condensed form showing weather conditions prevailing over the Northwest during November, 1905*—Continued.

Causal weather.												Resulting weather in Wisconsin.								
Date.	High.		Low.		Nearest rain during past 12 hours.	Temperatures, 24-hour changes, and precipitation.						Date.	Temperatures, 24-hour changes, and precipitation.							
	Location.	Strength.	Location.	Strength.		Moorhead.	Bismarck.	Huron.	Pierre.	Omaha.	N. Platte.		La Crosse.		Madison.		Green Bay.		Milwaukee.	
													a. m.	p. m.	a. m.	p. m.	a. m.	p. m.	a. m.	p. m.
		Inches.		*Inches.*																
26	Dakotas Saskatchewan	30.0 30.1	East Ontario	29.7	Montana, Lake Superior.	28	20 −10	24 − 8	30 − 6	36	28	27	30	36 + 6 .16	30	36 ..... T.	28 − 6	36 + 6	38	40 + 6 .....
27	Saskatchewan	30.5	Utah	29.3	Dakotas, Montana	22 − 6 .04	16 ..... .04	30 + 6	30 ..... T.	36	32	28	44 +14 .68	36 ..... T.	44 +14 .80	42 + 6	38 +10 .48	38	42 ..... .36	52 +12 .....
28	Saskatchewan	30.4	Minnesota	29.15	Wisconsin, Iowa, Dakotas, Minnesota.	22 ... .96	6 −10 .52	28 ..... .68	16 −14 .36	36 ..... .36	24 − 8 .08	29	18 −26 T.	10 −26	20 −24 T.	16 −26 T.	28 −10 T.	14 −24 T.	26 −16 T.	22 −30 T.
29	West Dakotas	30.6	East Ontario	29.4	Wisconsin, Iowa, Dakotas, Minnesota.	− 6 −28 .38	− 8 −14 .22	0 −28 .04	2 −14 .10	8 −28 T.	6 −18 .24	30	2 −16	18 + 8	8 −12	18	10 −18	18	12 −14	26 ..... T.
30	Minnesota	30.8	Utah British Columbia.	29.9 29.8	Upper Michigan, Oregon	−26 −20	−14 − 6	−12 −12	− 6 − 8	4	4	Dec. 1	22 +20	....	20 +12	26 + 8	26 +16	32 +14	30 +18	32 + 6 .....

The rules obtained by this method are of course largely empirical and are not to be depended upon absolutely in making practical forecasts. Watchfulness of local conditions and careful consideration of the daily peculiarities and abnormalities in the regular march of weather conditions across the country are of much importance for making accurate local forecasts. On the other hand it will hardly be possible for anyone who has a fair knowledge of meteorological phenomena to pursue the study of the problem of forecasting as outlined above without obtaining a better knowledge of its fundamental principles.

SPECIMEN RULES.

From a limited amount of data the following specimen rules for the month of November have been formulated, applicable particularly to the southern portion of Wisconsin.

1. A decided 24-hour rise in temperature (20° or more) in eastern South Dakota, closely attending a low, except when no rain has fallen in the Northwest, indicates rain the following night in Wisconsin.
2. A decided low (central isobar 29.3 inches or lower) in the Southwest (Kansas, Colorado, or Utah), with rain in North Dakota, indicates rain the next night period.
3. A general rise of temperature in the Dakotas, amounting to 6° or more, accompanied by rain in the Southwest (Oklahoma and Kansas) indicates rain either the next night or the following day.
4. A. M. rain in Nebraska, except when attending a fall in temperature, will be followed by rain in one of the periods forecasted for.
5. A distinct high in Iowa, Kansas, or Missouri, with a low northwest of it, will be followed by rising temperature in both periods. Exceptions: The high over Kansas must be 30.4 inches, or more, at center; when the temperature is comparatively very low in the Dakotas, no rise will follow.
6. A decided rise of temperature in the Dakotas, attending a low, indicates a rise in the a. m. period.
7. A low in Alberta or British Columbia, unless disturbing pressure centers intervene, indicates a p. m. temperature rise.
8. A decided low in the Southwest will cause an a. m. temperature rise.
9. A 20° fall in temperature in the Dakotas, following a low, indicates an a. m. fall in temperature.
10. A low (central isobar 0.2 inch below the normal) over Minnesota, Superior, or Wisconsin, except when there has been a decided rise in the Dakotas, indicates an a. m. temperature fall.
11. A similar low over Minnesota indicates a p. m. temperature fall.
12. Fair weather, with stationary temperature, is generally indicated in all cases not covered by the preceding rules.

The foregoing rules, applied to the data from which they were derived, gave forecasts with a verification (under the present system) of 94 per cent for precipitation, and 85 per cent for temperature. These percentages would not of course hold absolutely for other data, but it would seem that any loss in percentage of verification should be partially compensated by the forecaster's familiarity with the existing weather movement.

THE EVAPORATION OF ICE.[1]

By F. C. MITCHELL, Camden, Me.

The object of this series of experiments on the evaporation of clear ice and snow is to determine to what degree the evaporation is affected by (*a*) temperature, (*b*) amount of atmospheric pressure, (*c*) velocity of wind, and (*d*) area of exposed surface.

Experiments have been performed on the evaporation of liquids and several laws stated, and it has been assumed that the laws for the evaporation of solids like ice follow those for liquids.

Dalton stated that:

> Evaporation is that process by which liquids and *solids* assume the gaseous state at their free surfaces. The *rate* of evaporation depends upon temperature of the liquid or *solid*, the extent of the exposed surface, and the facility with which the gaseous particles can escape from the neighborhood of the surface either by diffusion through the air or by the motion of the air itself.

This is equivalent to saying that evaporation of liquids and solids depends upon temperature, amount of exposed surface, atmospheric pressure, humidity, and wind.

The evaporation of a liquid may be seen at any time, and that of a solid such as ice may be observed in the winter and spring, when snow disappears with the temperature continuously below 0° C. Some chemical substances, such as camphor and iodine, evaporate at ordinary pressure and temperature without first passing into the liquid state.

Two different methods were used in my experiments, which continued thruout the first three weeks of the month of March, 1906, whenever the temperature remained below 0° C. During the first two weeks of the month the conditions were

[1] These investigations were suggested to me by Prof. James S. Stevens, of the University of Maine, and presented as a thesis to the department of physics of that institution, at Orono.